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Swine Feed Management and Diet Options to Reduce Nitrogen Excretion in U.S. Swine Production

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Summary

Nitrogen (N) excreted in swine manure is nitrogen that is not utilized by the animal to produce meat. Excreted N is the difference between the N a pig consumes and the N it retains in body tissue, so nitrogen retention strategies either lower dietary N intake or improve the conversion efficiency of dietary N to lean tissue. This publication reviews the feed management and diet formulation options available to U.S. swine producers to reduce N excretion in manure, summarizes the reductions reported in the peer-reviewed literature, and identifies the practices that are already in routine commercial use. Reducing dietary crude protein (CP) while supplementing crystalline amino acids (AA) is the single most effective option, with published work reporting reductions in total N excretion of approximately 8 to 10 percent for each one percentage point reduction in dietary CP. Increasing the number of feeding phases, split-sex feeding, formulating on a standardized ileal digestible (SID) amino acid basis, controlling feed wastage and adopting precision feeding technologies can provide additional reductions. Selected feed additives, including exogenous protease, fermentable fiber sources and acidifying agents, such as benzoic acid or calcium benzoate, primarily reduce the conversion of excreted N to ammonia rather than total N excretion. Reducing CP and supplementing crystalline amino acids, phase feeding and wet-dry feeders have become core practices with the majority of U.S. swine producers utilizing them. Applied together, these strategies can reduce swine manure N by 20 to 40 percent relative to diets formulated to total CP with wide safety margins.

Introduction

Nitrogen is supplied to pigs as dietary protein and amino acids and is required for lean tissue growth, maintenance, immune function and reproduction. Pigs are inefficient users of dietary N. Under typical commercial conditions, growing-finishing pigs retain only about 30 to 45 percent of ingested N in body tissue, and the remainder is excreted in urine and feces (Aarnink and Verstegen, 2007; Dourmad and Jondreville, 2007). The fecal and urine excretion routes are not equivalent from an environmental standpoint. Fecal N is largely bacterial and undigested dietary protein and is relatively stable, whereas urinary N is dominated by urea, which is rapidly hydrolyzed to ammonia by microbial urease present in feces and on manure-contact surfaces

(Aarnink and Elzing, 1998; Canh et al., 1998a). Because urea hydrolysis begins within hours of excretion, the urinary N fraction governs ammonia volatilization from swine manure.

Nitrogen excretion is important to swine producers in regard to both animal production and manure nutrient management. Protein and amino acids are among the most expensive components of the diet, so N fed in excess of requirement is a direct economic loss. Manure N also directly impacts the land base required for manure application under N-based nutrient management plans.

Feed management and diet formulation are the most cost-effective methods for decreasing N excretion because they act at the source. Reductions achieved in the diet propagate through the entire manure management system, resulting in less nitrogen in manure at every downstream stage. Lower manure N can potentially reduce the total ammonia lost during storage, and the total amount of N to be land applied (Rotz, 2004; Ndegwa et al., 2008). This publication addresses the diet formulation and feed management options available for reducing N excretion, quantifies their documented effects, and discusses their practical implementation in U.S. swine production.

Nitrogen Utilization and Excretion in Swine

The mass balance that governs swine manure N content is straightforward. Nitrogen excreted in manure equals the N consumed by the pig, minus the N retained by the pig. Nitrogen consumed is the product of feed intake and dietary N concentration, where dietary CP is estimated as N multiplied by 6.25. Nitrogen retained is determined by the pig's protein deposition rate, which is determined by genetics, sex, body weight, health status and environment. Reductions in excreted N can be achieved by reducing the amount of N consumed by the pig or increasing the fraction of N retained in the pig. Published standard values for manure production and characteristics provide the baseline against which these dietary reductions are evaluated (ASABE, 2005).

Excess dietary amino acids cannot be stored. Amino acids absorbed in excess of the requirement, or amino acids that cannot be used because a first-limiting amino acid is deficient, are deaminated in the liver, the carbon skeleton is used for energy or fat synthesis, and the amino group is converted to urea and excreted in urine (Kerr and Easter, 1995). This is why an imbalanced diet with adequate total CP can excrete more N than a lower-CP diet with a correct amino acid profile. It is also why formulating to total CP or total amino acids overstates the nutritional value of poorly digestible protein sources and increases swine N excretion.

The ideal protein concept addresses this directly. All essential amino acids are expressed as a ratio to lysine, and the diet is formulated so that lysine is the first-limiting amino acid at the requirement level, with all other amino acids supplied at or just above their ideal ratio (NRC, 2012). Formulating on a standardized ileal digestible (SID) basis, rather than on total amino acid content, accounts for differences in amino acid digestibility among ingredients and corrects for basal endogenous losses. Together, the ideal protein concept and SID formulation permit substantial reductions in dietary CP without loss of pig performance, provided the amino acids that become limiting as CP falls are supplied in crystalline form (Wang et al., 2018; Cappelaere et al., 2021).

Diet Formulation Strategies

Reduced crude protein, amino acid-supplemented diets. Replacing intact protein with crystalline amino acids allows the diet to meet amino acid requirements at a lower total N

concentration, which directly lowers the quantity of N excreted per pig. The reported response is consistent across production phases, with each one percentage point reduction in dietary CP reducing total N excretion by approximately 8 to 10 percent, and the reduction occurring almost entirely in the urinary fraction (Kerr and Easter, 1995; Canh et al., 1998a; Sutton et al., 1999; Kerr et al., 2006). Because urinary N is the urea-rich, rapidly hydrolyzed fraction, the reduction also shifts manure N toward the more stable fecal organic fraction, improving the retention of N in stored manure. Kerr and Easter (1995) reported that lowering dietary CP by four percentage points with supplemental amino acids reduced N excretion in grow-finish pigs by roughly 30 percent without impairing performance, and Canh et al. (1998a) observed a comparable decline in total and urinary N excretion when dietary CP was lowered from approximately 16.5 to 12.5 percent in grow-finish pigs. Kerr et al. (2006) likewise documented reduced manure N concentration as dietary CP decreased. Panetta et al. (2006) and Powers et al. (2007) quantified reductions in N excretion from pigs fed reduced-CP diets under controlled conditions, and Otto et al. (2003) reported lower manure N and nitrogenous odorous compound concentrations from growing pigs fed diets reduced in CP and supplemented with amino acids. Hayes et al. (2004) confirmed the same directional response in commercial-scale finishing facilities. Practical reductions of two to four percentage points of CP are achievable in grow-finish diets, one to three points in nursery diets, and two to three points in gestation diets, corresponding to expected excreted N reductions of roughly 16 to 40 percent in grow-finish, 8 to 30 percent in nursery, and 14 to 21 percent in gestation, provided that the limiting amino acids are supplied and diets are phase-fed to closely match requirements, consistent with the requirement estimates in NRC (2012).

Phase feeding. Amino acid requirements per unit of energy decline continuously as pigs grow, while a fixed diet delivers a constant amino acid concentration. Any single diet therefore oversupplies amino acids for most of the period over which it is fed. Increasing the number of grow-finish diet phases from two or three to four, five or six more closely tracks the requirement curve and typically reduces N excretion by 5 to 10 percent with no loss of performance (Pomar et al., 2009).

Split-sex and split-population feeding. Barrows and gilts differ in lean growth rate, feed intake and lysine-to-calorie requirement, and immunologically castrated or intact males differ from both. Feeding these groups separately allows each to be fed nearer its own requirement rather than to the requirement of the most demanding group in the population. Sorting light and heavy pigs, where facilities permit, provides a comparable benefit and narrows marketing weight variation.

Precision feeding. Automated feeders that blend a custom ration for each pig daily, based on recorded individual body weight and feed intake and a growth model, represent the current upper limit of dietary N reduction. Andretta et al. (2016) reported that precision feeding of growing pigs reduced lysine intake by approximately 26 percent and estimated N excretion by approximately 30 percent, with no adverse effect on growth performance, relative to conventional phase feeding of groups. Pomar and Remus (2019) reviewed the technology and reported N excretion reductions on the order of 30 percent. Precision feeding requires electronic identification, individual intake recording, and integration with a growth model, so adoption in U.S. commercial grow-finish barns remains limited, but the approach establishes the magnitude of the oversupply inherent in feeding groups of pigs to their mean.

Tightening safety margins. Much of the N oversupply in commercial diets is not nutritional but procedural. Diets formulated to legacy specifications, to total rather than SID amino acids or

with arbitrary insurance margins on CP and amino acids excrete N that produces no growth response. Using current requirement estimates (NRC, 2012; Kansas State University, 2026; supplier and breeding-company recommendations), adopting a net energy basis for energy evaluation so that amino acid-to-energy ratios remain correct when fiber or fat inclusion changes, and justifying safety margins by measured ingredient variability rather than by routine practice are all low-cost or no-cost N reduction measures.

Feed Additives

Several additive classes contribute to reduced N excretion or reduced ammonia volatilization. Exogenous protease improves protein and amino acid digestibility and can support modest reductions in dietary CP or soybean meal inclusion. Carbohydrases, including xylanase and beta-mannanase, improve nutrient release in high-fiber and co-product diets. Phytase, although used principally to reduce phosphorus excretion, produces limited improvements in amino acid and N digestibility as well (Jacela et al., 2010). Direct-fed microbials and prebiotics have been reported to improve N retention, although responses are variable across studies and conditions. Fermentable fiber sources shift N excretion from urinary urea toward fecal microbial N and lower slurry pH, and combining reduced dietary CP with fermentable carbohydrate reduces both ammonia and odor emission (Canh et al., 1998b; Zervas and Zijlstra, 2002; Shriver et al., 2003; Le et al., 2008).

Acidifying additives act primarily on emission rather than excretion. Benzoic acid and calcium benzoate lower urinary pH, which reduces the equilibrium concentration of free ammonia available for volatilization. Mroz et al. (2000) reported that dietary calcium benzoate altered dietary buffering capacity, improved nutrient retention, and changed manure characteristics in swine, and Kluge et al. (2006) reported improved nutrient digestibility and altered microbial metabolism in piglets fed benzoic acid. Organic acid blends and manipulation of dietary electrolyte balance through the use of acidifying salts operate through the same mechanism and have been reported to reduce ammonia volatilization by 10 to 20 percent or more. Van Kempen (2001) reported that dietary adipic acid reduced ammonia emission from swine excreta. Saponin sources such as Yucca schidigera, condensed tannins and essential oils are marketed for ammonia binding or suppression of microbial deamination; these products may reduce emission but do not reduce the quantity of N excreted and should be evaluated on this basis.

Feed and Feeder Management

Feed that is wasted is fully excreted N with no production gain. Feed wastage of 5 percent increases manure N loading by approximately the same proportion, and wastage at this level or higher is common where feeder adjustment is not routinely monitored. Feeder gap adjustment on a defined schedule, staff training on correct feeder adjustment and selection of feeder design appropriate to the production phase are therefore among the highest-return N reduction practices available, and they require no change in diet formulation. Wet-dry feeders generally reduce wastage and improve feed conversion relative to conventional dry feeders.

Feed processing and delivery also affect N efficiency. Reducing corn particle size to approximately 500 to 700 micrometers improves nutrient digestibility, with the lower bound set by flowability and gastric ulcer risk. Pelleting improves nutrient digestibility and reduces wastage where pellet quality is maintained and fines are controlled. Mixer accuracy and mix time must be verified by coefficient of variation testing, because crystalline amino acids are added at low inclusion rates and are of no value if they are not uniformly distributed. Feed budgeting by

pounds per pig per phase prevents overfeeding of high-CP early diets past the point of requirement. Finally, water delivery management, including nipple height and flow rate calibration, reduces spillage and slurry volume and decreases manure dilution.

Herd Health and Production Management

Nitrogen retention is a function of the pig as well as the diet. Selection for feed efficiency and lean growth increases N retained per unit of N consumed. Disease, thermal stress and high stocking density increase protein catabolism and reduce protein deposition, so health interventions, ventilation management and stocking density control are indirect N reduction tools (Kerr et al., 2003). Mortality and removals are a particularly direct loss: all feed consumed by a pig that never reaches market is excreted N with no marketable product. Narrowing weight variation at marketing reduces the number of pigs fed beyond their efficient window. In the breeding herd, matching gestation feeding to sow parity and body condition, using reduced CP gestation diets with supplemental amino acids, and ensuring adequate lactation amino acid supply to prevent excessive body protein mobilization all reduce N excretion per pig weaned.

Quantitative Summary of N Excretion Reduction Potential

Table 1 summarizes the reductions in nitrogen excretion or ammonia emission reported in the literature for the strategies discussed above. Reductions are not strictly additive, because several strategies act on the same pool of oversupplied nitrogen, but combining reduced-CP formulation with increased phase count, split-sex feeding, and wastage control has been reported to reduce manure N by 20 to 40 percent relative to a single-diet, total-CP formulation with wide safety margins.

Strategy	Reported effect on nitrogen excretion or ammonia emission	Primary phase of application	Source(s)
Reduced CP with crystalline amino acids	Approximately 8–10% reduction in total N excretion per one percentage point reduction in dietary CP; ammonia emission reduced by a similar or greater proportion because the urea-rich urinary fraction is preferentially reduced	All phases; 2–4 points CP in grow-finish	Kerr and Easter, 1995; Canh et al., 1998a; Sutton et al., 1999; Kerr et al., 2006
SID amino acid and ideal protein formulation	Enables low-CP formulation; prevents oversupply from digestibility differences among ingredients	All phases	NRC, 2012; Wang et al., 2018
Increased number of feeding phases	Approximately 5–10% reduction in N excretion moving from 2–3 to 4–6 grow-finish phases	Grow-finish	Pomar et al., 2009
Split-sex feeding	Reduces amino acid oversupply to the lower-requirement sex; typically a few percent of total N	Grow-finish	NRC, 2012 (requirement estimates)
Precision (individual) feeding	Approximately 25–30% reduction in lysine intake and about 30% reduction in estimated N excretion	Grow-finish	Andretta et al., 2016; Pomar and Remus, 2019
Fermentable fiber inclusion	Shifts N from urinary urea to fecal microbial N; lowers slurry pH and reduces ammonia emission substantially with little change in total N	Grow-finish; gestation	Canh et al., 1998b; Zervas and Zijlstra, 2002; Shriver et al., 2003

Strategy	Reported effect on nitrogen excretion or ammonia emission	Primary phase of application	Source(s)
Acidifying additives (benzoic acid, calcium benzoate, organic acids, reduced dietary electrolyte balance)	Lowers urinary and slurry pH; reported ammonia emission reductions of 10–20% or more; total N excretion largely unchanged	Nursery; grow-finish	Mroz et al., 2000; van Kempen, 2001; Kluge et al., 2006
Exogenous enzymes (protease, carbohydrases, phytase)	Improves protein and amino acid digestibility, supporting modest additional CP reduction	All phases	Jacela et al., 2010
Feed wastage control and feeder management	Wastage reduction translates approximately one-for-one into reduced manure N loading; 5% wastage equals about 5% excess N	All phases	Rotz, 2004
Health, mortality, and marketing weight uniformity	Improves N retained per unit of N fed; feed consumed by pigs not marketed is excreted entirely	All phases	Kerr et al., 2003; Aarnink and Verstegen, 2007

Note: Values are reported ranges from the cited literature and depend on the baseline diet, production phase, genetics, and housing system. Acidifying additives reduce ammonia emission without reducing total nitrogen excretion conserve manure fertilizer nitrogen value but do not reduce the nitrogen mass requiring land application.

Nitrogen Reduction Efficiency by Pig Production Type

Nitrogen reduction efficiency is not uniform across the production cycle. The achievable reduction in excreted N depends on the size of the gap between the N supplied by the diet and the N the animal can retain, and that gap differs between the breeding herd, the nursery and the grow-finish phase. Sows are fed for maintenance and reproduction rather than maximum lean growth, nursery pigs are fed the most nutrient-dense and most conservatively formulated diets in the system and growing-finishing pigs consume approximately 75 to 80 percent of the total feed used per pig marketed. The following summarizes the N reductions reported by production type.

Sows (gestation and lactation). Gestating sows retain N with high efficiency when diets are balanced on a standardized ileal digestible amino acid basis, which limits how much additional improvement diet reformulation can deliver. Ibagon et al. (2026) fed gestating sows a corn-soybean meal diet containing 14.1 percent CP or a reduced-CP diet containing 11.2 percent CP with crystalline amino acids and measured N balance in metabolism crates. The approximately three percentage point reduction in dietary CP lowered daily N intake by 24 percent, urinary N excretion by 25 percent (20.5 to 15.4 g/d), fecal N excretion by 10 percent (6.8 to 6.1 g/d), and total N excretion by approximately 21 percent, or roughly 7 percent per percentage point of CP removed. Nitrogen retention expressed as a percentage of intake was not different between diets (47.8 versus 45.9 percent), and reproductive performance, litter size, litter weaning weight, and sow feed intake were unaffected (Ibagon et al., 2026). Two cautions apply to the breeding herd. First, daily N retention in grams was lower on the reduced-CP diet, indicating that crystalline amino acids were not used as efficiently as amino acids from intact soybean protein, and sow body weight at day 104 of gestation was reduced. Second, milk fat, protein, lactose and immunoglobulin G concentrations and several antioxidant and immune indicators were lower on the reduced-CP diet (Ibagon et al., 2026). Reduced-CP gestation diets should therefore be implemented with moderate CP reductions of two to three percentage points, adequate intact

protein, and monitoring of body condition. In lactation, N reduction potential is larger in absolute terms because feed intake is high, but the requirement for milk protein synthesis is also high, and reported reductions in N excretion are accompanied by increased mobilization of body protein when dietary amino acid supply is inadequate (Huber et al., 2015).

Weaned and growing nursery pigs. Nursery diets carry the largest procedural safety margins in the system. The percentage reduction in N excretion available per percentage point of CP is comparable to that in other phases, but the practical floor is set by growth performance and by the supply of functional amino acids rather than by N balance. Son and Kim (2023) fed 15-kg pigs diets containing 19.4, 17.5 or 15.7 percent CP, all supplemented to meet essential amino acid requirements, and reported linear decreases in both fecal and urinary N excretion, a linear increase in N retention as a percentage of intake, and linear decreases in urine pH and slurry pH as dietary CP declined. The reduction in slurry pH is important because it lowers the fraction of ammoniacal N present as free ammonia and therefore reduces emission independently of the reduction in excreted N. Teixeira et al. (2025) fed weaned pigs 22.5, 21.0, 19.5 or 18.0 percent CP diets and reported reduced fecal N excretion and a lower incidence of diarrhea as CP declined, but also poorer feed conversion and reduced nutrient digestibility at the lowest CP level, which was not corrected by supplemental arginine and glutamine-glutamate. Practical guidance is consistent with these results: initial nursery diets formulated at up to 22 percent CP can be reduced to approximately 18 percent CP when feed-grade amino acids are used, which reduces both soybean meal and specialty protein inclusion (Kansas State University, 2026). Reductions of one to three percentage points of CP are therefore realistic in most nursery diets, and up to four points in the highest-CP starter diets, corresponding to roughly 8 to 10 percent lower total N excretion per point, with the limit set by post-weaning growth rather than by N metabolism. Because the nursery phase accounts for a small share of lifetime feed intake, the whole-farm N benefit of nursery reformulation is modest relative to grow-finish.

Grow-finish pigs. The grow-finish phase offers the largest absolute N reduction because it accounts for the majority of feed consumed and manure produced. Mulvenna et al. (2025) fed pigs from approximately 40 kg to 112 kg either a 175 g/kg CP control diet or diets containing 150 g/kg CP balanced to the ideal protein profile. The 2.5 percentage point reduction in CP reduced N intake by 15 percent and N excretion by approximately 21 percent, from 38.7 g/d to an average of 30.5 g/d, with no effect on overall feed intake, average daily gain, feed conversion or slaughter weight, and with N retention as a percentage of intake unchanged at an average of 41.9 percent. This corresponds to approximately 8 to 9 percent lower N excretion per percentage point of CP removed, consistent with the range reported by Canh et al. (1998a) and Kerr et al. (2006). Balancing the ideal protein profile only to lysine, methionine, and threonine was the most cost-effective formulation in that work, and soybean meal inclusion fell from 190 to 102 g/kg (Mulvenna et al., 2025). Monteiro et al. (2017) reported comparable reductions in nitrogen excretion and in the estimated environmental impact of growing-finishing pigs fed reduced-protein diets, with performance, carcass traits, and meat quality maintained. Ammonia emission responses in grow-finish are typically equal to or larger than the reduction in total N excretion because the urea-rich urinary fraction is preferentially reduced (Canh et al., 1998a; Hayes et al., 2004; Powers et al., 2007). Grow-finish diets are also where increased phase count, split-sex feeding and precision feeding deliver their documented reductions of 5 to 10 percent and approximately 30 percent, respectively (Pomar et al., 2009; Andretta et al., 2016).

Table 2 summarizes the reported N reduction efficiency by production type. Because grow-finish pigs consume most of the feed used per pig marketed, a given percentage reduction in N excretion achieved in grow-finish diets produces several times the whole-farm effect of the same

percentage reduction achieved in nursery or gestation diets, and grow-finish reformulation should therefore be the first priority where effort and capital are limited.

Production type	Typical dietary CP reduction	Reported effect on nitrogen excretion	Source(s)
Sows, gestation	Approximately 3 percentage points (14.1 to 11.2% CP)	N intake reduced 24%; urinary N reduced 25%; fecal N reduced 10%; total N excretion reduced approximately 21% (about 7% per percentage point); N retention as a percentage of intake unchanged and reproductive performance unaffected, but daily N retention in grams, sow body weight at day 104, and milk solids and immunoglobulin G were reduced	Ibagon et al., 2026
Sows, lactation	Approximately 2 to 3 percentage points	Reduced urinary N and N excretion per pig weaned; limited by milk protein synthesis and by body protein mobilization; milk solids and immunoglobulin G reduced at the lowest CP level	Huber et al., 2015; Ibagon et al., 2026
Weaning to nursery exit (weaning-growing pigs)	1 to 3 percentage points typical; up to 4 points in high-CP starter diets (approximately 22 to 18% CP)	Linear reductions in fecal and urinary N; N retention as a percentage of intake increased; urine and slurry pH reduced, lowering ammonia emission; growth and digestibility limit further reduction	Son and Kim, 2023; Teixeira et al., 2025; Kansas State University, 2026
Grow-finish	2 to 4 percentage points (approximately 17.5 to 13.5% CP; 17.5 to 15.0% CP in the cited study)	N intake reduced 15% and N excretion reduced approximately 21% at a 2.5-point reduction (about 8 to 9% per percentage point); performance and carcass traits unaffected; ammonia emission reduced equally or more	Mulvenna et al., 2025; Canh et al., 1998a; Kerr et al., 2006

Note: Values are reported ranges from the cited literature. Reductions per percentage point of crude protein are similar across production types; the whole-farm effect differs because growing-finishing pigs consume approximately 75 to 80 percent of the feed used per pig marketed. Strategies that lower urine or slurry pH reduce ammonia emission without reducing the nitrogen mass requiring land application.

Conclusion

Nitrogen excretion in swine production is dominated by dietary nitrogen supplied in excess of the pig's amino acid requirement, and it is therefore largely controllable through diet formulation and feed management. Reducing dietary crude protein while supplementing crystalline amino acids on a standardized ileal digestible, ideal protein basis is the most effective single strategy, reducing total nitrogen excretion by approximately 8 to 10 percent per percentage point of crude protein removed and reducing ammonia emission by a similar or greater proportion (Kerr and Easter, 1995; Canh et al., 1998a; Kerr et al., 2006). Management practices can provide additional excreted N reductions. Increasing the number of grow-finish phases from two or three to four through six reduces excreted nitrogen by 5 to 10 percent, split-sex feeding by a few percent of total nitrogen, and precision individual feeding by approximately 30 percent. Eliminating feed wastage returns excreted nitrogen reductions approximately one for one with the wastage removed, so correcting 5 percent wastage removes about 5 percent of manure nitrogen at essentially no cost. Acidifying additives and fermentable fiber shift the form and the fate of excreted nitrogen, cutting ammonia emission by 10 to 20 percent or more, but they do not reduce

the nitrogen mass requiring land application and should not be credited as excretion reductions. Not all of these methods are additive, because several of them act on the same pool of oversupplied nitrogen. A realistic expectation for a commercial operation that combines reduced crude protein formulation on a standardized ileal digestible basis, additional feeding phases, split-sex feeding and disciplined feeder management is a 20 to 40 percent reduction in manure nitrogen relative to a single-diet, total crude protein formulation carrying wide safety margins. Because grow-finish pigs consume approximately 75 to 80 percent of the feed used per pig marketed, the same percentage reduction applied in grow-finish diets yields several times the whole-farm effect of that achieved in nursery or gestation diets, and grow-finish reformulation is therefore the first priority where effort and capital are limited. While no recent national survey statistics tracking the exact percentage of U.S. pig producers who replace crude protein with amino acids are available, industry data and nutritional reports indicate that over 90 percent large-scale and commercial U.S. swine operations use synthetic or crystalline amino acids to balance rations and lower intact crude protein, and over 80 percent implement phase feeding. Because these practices reduce feed cost, they are economically justified independent of any environmental requirement and are currently commonly in use by the U.S. swine industry.

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